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Journal of Colloid and Interface Science 281 (2005) 307–315
JOURNAL OF Colloid and Interface Science
www.elsevier.com/locate/jcis

Surface characterization of cotton coated by a thin film of polystyrene with and without a cross-linking agent

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Received 16 March 2004; accepted 11 August 2004

Abstract

Thin polystyrene film coated on cotton was successfully formed by admicellar polymerization. Divinylbenzene (DVB) was used as a cross-linking agent to form networked polystyrene to improve film coverage. A wettability test and XPS analysis were used to characterize the coated surface. The optimum amount of DVB was around 1%. At this amount, the film coverage was most complete, as judged by the reduction of the O1*s* signal in XPS analysis.

Keywords: Cotton; Polystyrene film; Cross-linking agent; Divinylbenzene; XPS; Admicellar polymerization; Wettability

1. Introduction

Thin film coatings are widely used for modification of substrate surfaces. Common methods for applying thin film coatings include chemical vapor deposition, plasma polymerization, physical vapor deposition, and electrochemical deposition. Admicellar polymerization is a method that can be used to create a thin polymeric film on a substrate surface [1]. The method makes use of the formation of a surfactant bilayer on a substrate surface at a surfactant concentration just below the CMC. In the outer surfactant layer, the amphiphilic molecules are oriented with their ionic head groups in contact with the aqueous solution, while the long hydrophobic tails interact to form a hydrophobic inner core (Fig. 1a). An inner layer oriented with the head groups in contact with the substrate completes the surfactant bilayer called an "admicelle." When an organic monomer is added into the solution, it will be preferentially adsorbed in the core of the admicelle in a process called "adsolubilization," and when an initiator is added, the monomer in the admicelle will undergo a polymerization reaction to form a polymeric layer on the substrate surface (Fig. 1b). After the polymerization, surfactant in the upper layer may be removed by washing to expose the polymeric layer on the substrate surface (Fig. 1c).

Admicellar polymerization has been successfully used to coat thin films of a variety of polymers on various kinds of substrates for several purposes, such as hydrophobicity coating on an organic substrate [2,3], hydrocarbon component coating on inorganic materials [4–6], and electropolymer coating on surfaces [7,8]. Recently, the method has been used to form a thin polystyrene film on cotton [2]. The resulting cotton fabric shows good water repellency. Water-repellent cotton has wide applications in tentage material, canvas, raincoats, and furnishing textiles. Polystyrene is known to form a networked polymer with a cross-linking agent such as divinylbenzene (DVB) [9], shown in the reaction scheme in Fig. 2. Many studies have been carried out on various aspects of the reaction [10,11]. In this work the effect of adding DVB to the styrene monomer in the admicellar polymerization process on cotton was studied. After the polymerization, the wettability of the treated cotton sur-

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0021-9797/$ – see front matter
doi:10.1016/j.jcis.2004.08.090

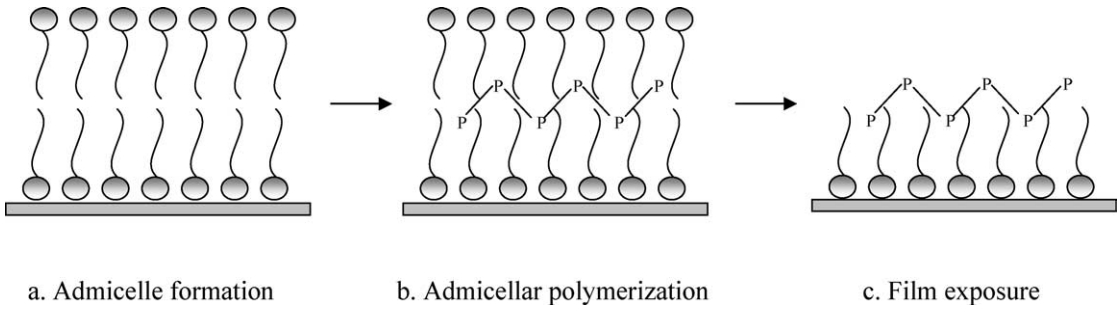

Fig. 1. Admicellar polymerization process.

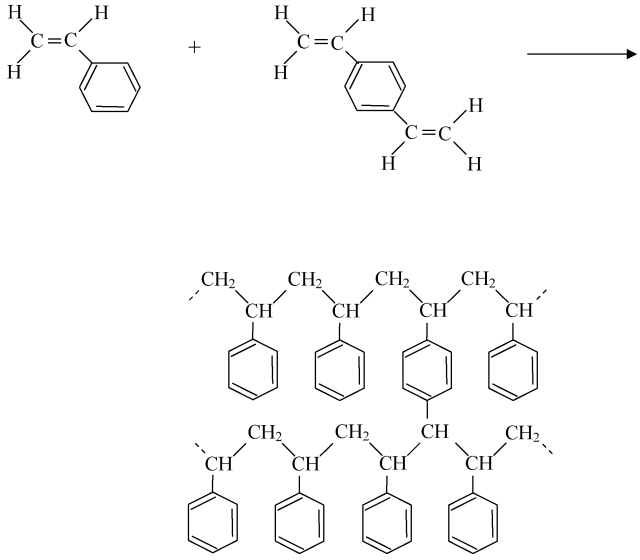

Fig. 2. The reaction of cross-linked polystyrene.

face as determined by the Wilhelmy microbalance technique was correlated to the surface coverage of the polymer as determined by XPS. The wettability of cotton and admicelle-modified cotton using the Wilhelmy microbalance technique was reported previously [12].

XPS is a powerful technique that is widely used for characterization of substrate surfaces [13,14]. It provides information about the chemical state and concentration of elements composing the outermost surface layer of a solid. The sample depth of this technique is generally less than 10 nm [15]. In this work it was used to characterize films of polystyrene coated on cotton in both qualitative and quantitative analysis. The peak C(1*s*) was qualitatively used to differentiate characteristic peaks between cotton and polystyrene and confirm that cotton fabric modified by admicellar polymerization was coated with polystyrene. The coverage and film thickness of polystyrene on cotton were quantitatively determined by XPS using the peak of O(1*s*), which has no signal for pure polystyrene, but occurs in cellulose of cotton. The coverage and thickness of the film were used to comparatively explain the wettability of different cotton samples prepared using various amounts of DVB.

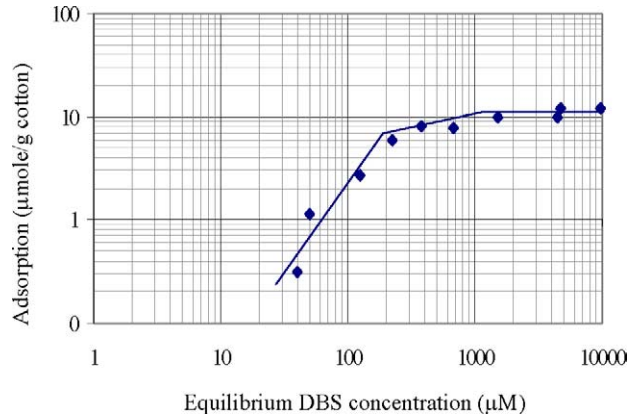

Fig. 3. Adsorption isotherm curve of DBS–cotton system.

2. Experimental

2.1. Materials

A plain weave, medium-weight (150 g/m^2) bleached cotton fabric was purchased from Boonchauy Co. Ltd. Prior to use, the fabric was washed several times in a washing machine at 95 °C until it was free from any remaining surfactant, as checked by the UV absorption of the last washing liquid at the wavelength of 225 nm.

Styrene monomer and divinylbenzene were purchased from Aldrich Co. Ltd. The inhibitors in both chemicals were removed by washing with 10% NaOH according to the method described by Collins et al. [16].

Dodecylbenzene sulfonate (DBS), used as the surfactant, was purchased from Aldrich Co. Ltd.

Sodium persulfate, used as an initiator, was purchased from BHD Laboratory Supplies Co. Ltd. Hydrochloric acid and sodium chloride were purchased from Merck Co. Ltd.

2.2. Admicellar polymerization process

The admicelle-enabled surface polymerization was carried out at a DBS concentration just below the CMC, as determined from the adsorption isotherm of the DBS–cotton system in the presence of 0.15 M NaCl at pH 4, as shown in Fig. 3. The concentration of DBS in solution was determined by a Cecil Model CE 2040 UV spectrophotometer at a wavelength of 225 nm, which is the wavelength of maximum